

Montana Department of Transportation



Working Paper #5: Level of Service and Safety

Final Draft

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1 INTRODUCTION

Overview

Safety and Level of Service are the two key issues that transportation planners and decision-makers at federal, state, and local levels aim at addressing. While level of service rating relates the overall efficiency of the roadway in facilitating the flow of traffic, overall accident rate or fatal accident rate of the roadway represents the safety performance of the roadway.

The level of service rating of a roadway relates how well the roadway is performing its primary function, allowing motorists to travel to their destinations in a timely and efficient manner. When level of service is high, traffic flows freely and without congestion, but as the level of service declines, vehicular interactions increase and traffic speeds decline due to the addition of traffic congestion.

In rural areas, congestion is not a major factor and therefore the focus is mainly on the safety of the roadways. Safety issues in rural areas can range from geometry related-issues which affect visibility (horizontal and vertical alignment), intersections, side slope conditions, clear zones, lack of passing lanes, truck volumes and speed differential.

There are many options available to address safety issues on rural highways. Each roadway segment can be analyzed to determine the appropriate treatment to improve safety. Some of the treatments can be improving the horizontal and vertical alignment of the roadway, providing flatter side slopes, providing clear zone, providing wider shoulders, providing auxiliary turn lanes where needed, providing passing lanes where needed, and expanding a two-lane facility to a four-lane facility where justified based on capacity and/or safety.

This paper addresses the capacity and safety issues as it relates to the TRED corridor. Given the findings, stated in Working Paper #4, pertaining to the projected high percentage of truck traffic in the next twenty years. The capacity analysis used the truck percentage of thirty.

2 LEVEL OF SERVICE

This section provides an overview of level of service (LOS), TRED level of service planning goals, and the existing capacity and level of service in the study area. Traffic volumes for the TRED corridor are compared with capacities to determine the current quality of service on the highway.

2.1 Levels of Service

2.1.1 Categories

Level of service is a method of measuring the vehicle capacity in an area. When the capacity of a roadway is exceeded, this condition results in congestion and a poor level of service. Six levels of service ranging from A to F are used to define congestion and the operating conditions on roadways, with LOS A representing the best operating conditions (free-flowing traffic) and LOS F the worst operating conditions (extremely congested, stop-and-go traffic). Table 1 illustrates the level of service for a two-lane, Class I highway (primary arterials connecting major traffic generators/daily commuter routes/primary links to state or national highway networks) according to highway capacity standards.

Table 1: Level of Service Criteria for Two-Lane Highways in Class I

Level of Service (LOS)	Level of Service Definitions	Percent of Time Spent Following Other Vehicles	Average Vehicle Speed (mph)
A	Motorists can travel at their desired speed. No more than 35% of the time is spent following other vehicles.	35%	55
B	Average speed of 50–55 mph. Demand for passing is high. 50% of the time is spent following other vehicles.	35–50%	50–55
C	Average speed of 45–50 mph. Noticeable increase in following traffic with reduction in passing opportunities.	50–65%	45–50
D	Unstable traffic flow. Passing demand is high but passing opportunities approach zero. Vehicle following length of 5 to 10 vehicles and average speeds of 40–45 mph.	65–80%	40–45
E	Average speed below 40 mph. 80% of the time is spent following other vehicles. Passing is virtually impossible.	80%	40

LOS F applies whenever the number of vehicles traveling on the highway exceeds the roadway capacity.
Average Vehicle Speed assumes a free-flow speed of 60 mph.
Source: Transportation Research Board 2000

2.1.2 Planning Goals

According to Table 1 above, level of service on two-lane rural highways is defined by speed and percent of time spent following other vehicles. As traffic levels increase, particularly with the presence of trucks and heavy vehicles, the amount of time vehicles spend following other vehicles increases. Speeds begin to decline slightly, the freedom to maneuver within the traffic stream is more noticeably limited, and drivers often experience reduced physical and psychological comfort. This decrease in speed and increase in time spent following other vehicles leads to both a decreased level of service and a possible increase in accident rates as drivers seek opportunities to pass.

Consistent with the Federal Highway Administration's functional classification criteria, the TRED corridor is a rural principal arterial, which applies to the highways that typically provide high travel speeds and the longest trip movements. A highway's functional classification determines which geometric design standards are applied for that facility. MDT's Road Design Manual contains geometric design and level of service guidelines for roads, based on functional classification. As a general design consideration, designers should strive for the highest level of service that is practical and is consistent with anticipated conditions. For principal arterials in level terrain, such as the TRED corridor, MDT has set a level of service objective of "B".

2.2 Existing and Future Level of Service

For the analysis of the level of service conditions on the TRED corridor, the study area was divided into three segments: MT 16 from the Port of Raymond to Plentywood, MT 16 from Plentywood to Culbertson, and US 2 from Culbertson to the North Dakota State line.

MDT has adopted the Highway Capacity Manual (HCM) as the standard methodology for calculating level of service. The HCM presents the nationwide criteria for performing capacity analyses for highway facilities. Included in Appendix A are the LOS calculation worksheets for the TRED corridor. The existing lane configuration was used in our analysis for both the existing traffic volumes and proposed future traffic volumes in 2036. future traffic volumes used in the capacity analysis are those from Working Paper #4 that have a 10% chance of exceeding in 2036.

2.2.1 Existing Level of Service

The existing level of service analysis used traffic volume, large-truck percentage, percent of passing zones, the number of access points (driveways, roads, etc.) per mile, and lane and shoulder width information provided by MDT in the analysis. Other factors, such as the type of terrain or the directional traffic split (the amount of vehicle traveling in each direction) were determined from local observation or by applying default values from the HCM, which is consistent with the guidance in MDT's Road Design Manual.

2.2.2 Future Level of Service

The future level of service analysis was performed using the same assumptions for the existing conditions with some modifications to account for the future peak travel period.

Table 2 illustrates the results of the analysis of existing (2006) and future (2036) level of service conditions for each segment of the TRED corridor. As shown in Table 2, the existing and future levels of service meet the guidelines of LOS “B” for this type of facility.

Table 2: TRED Corridor Current and Future Levels of Service

Segment	MDT LOS Guidelines	2006 LOS	2036 LOS ^a	Terrain
MT 16 from Port of Raymond to Plentywood	B	A	B	Level
MT 16 from Plentywood to Culbertson	B	A	B	Level
US 2 from Culbertson to the North Dakota State line	B	A	B	Level

^a The existing highway corridor was used with no improvements.

Table 2 above provides the level of service for the TRED corridor based on existing conditions and the year 2036, assuming no capacity-related improvements to the corridor. The future capacity analyses were performed using statistical median traffic volumes, as well as volumes for the 10-percent and 90-percent confidence intervals. As shown in Table 2, with the future traffic volumes for the 10-percent confidence interval (worst case scenario), the TRED corridor will operate at an acceptable LOS “B” in 2036 with no capacity related improvements. As shown in the LOS worksheets in the appendix, the LOS is at the upper end of the “B” range and close to the “C” range.

3 SAFETY ANALYSIS

With over 42,000 fatalities occurring annually on America's highways, improving highway safety performance is central component of the Federal Highway Administration's mission, accordingly, FHWA's website states, "Safety on our highways is FHWA's top priority." Highway safety is also listed as one of the three Federal Highway Administration's "Vital Few Priorities," comprising safety, congestion mitigation, and environmental stewardship and streamlining. Consequently, it is clear that FHWA considers safety improvements to be of critical importance when determining the validity of highway improvement projects.

Likewise the Montana Department of Transportation takes into account the safety benefits of transportation projects it considers undertaking. The importance of improving the safety of Montana's roadways is apparent as safety is framed as one of the key elements of MDT's mission statement.

"MDT's mission is to serve the public by providing a transportation system and services that emphasize quality, safety, cost effectiveness, economic vitality and sensitivity to the environment."

As government institutions charged with serving the public, increasing the safety performance of roadways is one of the primary methods that transportation agencies can use to increase the public welfare. It is because of this fact, that opportunities to improve the safety of the nation's roadways are a key consideration in transportation planning decisions.

The commitment to improving highway safety by both FHWA and MDT is evident by the central placement of safety within their mission statements. The importance of that commitment is clear; increasing the safety performance of roadways affects the public directly by reducing injuries, property damage, and fatalities. This reality is the motivation for this chapter's analysis.

3.1 Existing Research

An extensive search for the safety benefits of a 4-lane roadway compared to a 2-lane roadway was completed. However, no comparable routes to the TRED corridor were found. Therefore, conclusion from the studies in other corridors can not be used to draw conclusions in the TRED corridor.

3.2 Speed Limit Differential

The MT 16 and US 2 sections of the TRED corridor within the state of Montana are governed by dual speed limits; one limit for large trucks, and a 10 mph higher limit for passenger vehicles.

Because of this disparity in speed limits, it was hypothesized that an inherent unsafe driving environment existed. A 2003 study and a 2006 follow-up both by Garber et al. examined states with dual speed limits and ones without to determine if the dual speed limit states showed increased crash rates. The studies looked at six states, three of which maintained a uniform speed limit during the 1990's, Arizona, Missouri, and North Carolina. Two of the states examined changed to a dual speed limit during this time period, Idaho and Arkansas. And one state changed from a differential speed limit to a uniform speed limit, Virginia. The authors conducted statistical tests across road segments within each state to determine if there were any statistically significant increases in the crash rates across the groups of states. They found no consistent link to increased crash rates within the states that had dual speed limits.

These studies, however, only considered multi-lane interstate sections, focusing on the expected safety hazard where slower moving trucks are traveling in the right lane and faster moving cars are passing the larger trucks while traveling in the left lane of the four-lane highway. Because of this fact, the results may not reflect the true safety ramifications along two-lane rural roadways, such as those comprising the study area corridor.

3.3 Montana Crash Data

Montana crash data for the MT 16 and US 2 sections of the TRED study area corridor and other comparable rural two-lane roadways is provided in Table 3. The sections of roadways outside the study area corridor were selected because they exhibit similar traffic volumes and have similar fractions of overall traffic composed of large trucks. Crash rates and severity rates for overall traffic and for large trucks are shown in Table 3.

Table 3: Crash and Severity Rates for Various Rural Two-Lane and Four-Lane Montana Roadways 2001-2005 (Per Million VMT)

Roadway Segment	Milepost Start	Milepost End	Description	Segment AADT	Percent Trucks	Overall Crash Rate	Truck Crash Rate	Overall Severity Rate
N-1 (US 2)	645	667	Culbertson to North Dakota Border	1186	10.7%	1.40	0.78	3.44
N-34 (MT 16)	0	15.4	Saskatchewan Border to Plentywood	731	12.7%	0.15	0.39	0.60
N-22 (MT 16)	42.3	88.5	Plentywood to Culbertson	1028	14.4%	0.63	0.88	1.63
N-1 (US 2)	383.7	428.5	US-2 Havre to Fort Belknap	2727	8.7%	1.27	1.13	2.54
N-62 (MT 16)	0	36.6	Culbertson to Sidney	1142	12.1%	0.91	1.00	1.56
N-53 (MT 3)	3.5	46.7	Billings to Lavina	2181	13.0%	0.69	0.76	1.42
N-14(MT 3)	99	146	Harlowton to Lavina	1554	19.1%	0.95	0.55	1.86
N-8 (US 12) 4-lane	32.5	40.5	Helena to bottom of MacDonald Pass	3944	9.0%	2.07	0.93	2.75
N-14 (MT 3)4-lane w/ TWLTL	87.3	90.4	Great Falls to Jct. S227/S228	6202	9.4%	1.34	0.90	3.77

Segments that comprise the Montana portion of the TRED corridor are highlighted in bold

The crash and severity rates listed in the above table can be compared to the statewide averages for rural principal arterials on the National Highway System (NHS). The statewide average for the crash rate is 1.24 and for severity the rate is 2.88. As can be shown in the table above the only segment that is over the statewide average crash rate and severity rate is the segment of US 2 between Culbertson and the North Dakota Border.

The crashes were analyzed in more detail on the segments within the TRED corridor and the results are as follows:

	Single Vehicle	Multiple Vehicle Turning Related	Multiple Vehicle Passing Related	Involves Trucks
US 2 Culbertson to North Dakota Border	86.6%	9.0%	1.5%	6%
MT 16 Saskatchewan Border to Plentywood	100%			33%
MT 16 Plentywood to Culbertson	83.6%	3.6%	1.8%	18%

3.4 Projected Safety Conditions

The projected safety conditions were analyzed extensively in the US-2, Havre to Fort Belknap EIS for different lane configurations. The lane configurations analyzed were the No build, Improved 2-lane, Improved 2-lane with passing lanes, 4-lane undivided, and 4-lane divided. The US-2, Havre to Fort Belknap is a similar corridor to the TRED corridor as was shown in Table 3. The crash rate used in the EIS was for the years 1997 through 2001. The decrease in the crash rate with the above lane configurations are as follows:

	Crash Rate	Change From Existing Condition	Incremental Change
No build	1.51	0	0
Improved 2-lane	1.36	0.15	0.15
Improved 2-lane with passing lanes	1.26	0.25	0.10
4-lane undivided	1.22	0.29	0.04
4-lane divided	1.13	0.38	0.09

As can be shown above, the projected safety benefits for a 4-lane undivided facility is marginal over an improved 2-lane with passing lanes.

4 CONCLUSION

Concluding Remarks

- An improved 2-lane would provide the necessary capacity for this corridor to function adequately.
- With 30% trucks and the associated speed differential, a four-lane facility will help with the passing conflicts throughout the entire segment.
- US 2 from Culbertson to the North Dakota state line has an average crash rate and severity rate exceeding statewide averages.
- As the corridor approaches the design year traffic volumes, the corridor will be approaching LOS “C” conditions.
- With increasing traffic volumes, passing conflicts will increase.
- All options (Improved 2-lane, Improved 2-lane with passing lanes, 4-lane undivided, and a 4-lane divided) will reduce the crash rate, however, the incremental benefits of a 4-lane undivided improvement over an improved 2-lane with passing lanes are minimal.

5 APPENDIX: LEVEL OF SERVICE CALCULATIONS

Phone: Fax:
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Two-Way Two-Lane Highway Segment Analysis

Analyst Danielle Bolan
Agency/Co. MDT
Date Performed 10/14/2006
Analysis Time Period
Highway US 2
From/To Culbertson to ND State Line
Jurisdiction MDT
Analysis Year 2006
Description TRED Corridor

Input Data

Highway class	Class 1				
Shoulder width	2.5	ft	Peak-hour factor, PHF	0.88	
Lane width	12.0	ft	% Trucks and buses	7	%
Segment length	22.5	mi	% Recreational vehicles	4	%
Terrain type	Level		% No-passing zones	31	%
Grade: Length		mi	Access points/mi	5	/mi
Up/down		%			
Two-way hourly volume, V	190	veh/h			
Directional split	60 / 40	%			

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.953	
Two-way flow rate, (note-1) vp	226	pc/h
Highest directional split proportion (note-2)	136	pc/h
Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	62.0	mi/h
Adj. for lane and shoulder width, fLS	2.6	mi/h
Adj. for access points, fA	1.2*	mi/h
Free-flow speed, FFS	58.2	mi/h
Adjustment for no-passing zones, fnp	1.2	mi/h
Average travel speed, ATS	55.2	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.993	
Two-way flow rate, (note-1) vp	217	pc/h
Highest directional split proportion (note-2)	130	
Base percent time-spent-following, BPTSF	17.4	%
Adj. for directional distribution and no-passing zones, fd/np	11.8	
Percent time-spent-following, PTSF	29.2	%

Level of Service and Other Performance Measures

Level of service, LOS	A	
Volume to capacity ratio, v/c	0.07	
Peak 15-min vehicle-miles of travel, VMT15	1214	veh-mi
Peak-hour vehicle-miles of travel, VMT60	4275	veh-mi
Peak 15-min total travel time, TT15	22.0	veh-h

Notes:

1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.

HCS2000: Two-Lane Highways Release 4.1c

Phone: Fax:
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Two-Way Two-Lane Highway Segment Analysis

Analyst Danielle Bolan
Agency/Co. MDT
Date Performed 10/14/2006

Analysis Time Period design hour
 Highway US 2
 From/To Culbertson to ND State Line
 Jurisdiction MDT
 Analysis Year 2036 - 90% Confidence
 Description TRED Corridor

Input Data

Highway class	Class 1				
Shoulder width	2.5	ft	Peak-hour factor, PHF	0.88	
Lane width	12.0	ft	% Trucks and buses	30	%
Segment length	22.5	mi	% Recreational vehicles	4	%
Terrain type	Level		% No-passing zones	31	%
Grade: Length		mi	Access points/mi	5	/mi
Up/down		%			
Two-way hourly volume, V	317	veh/h			
Directional split	60 / 40	%			

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.826	
Two-way flow rate, (note-1) vp	436	pc/h
Highest directional split proportion (note-2)	262	pc/h
Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	62.0	mi/h
Adj. for lane and shoulder width, fLS	2.6	mi/h
Adj. for access points, fA	1.2*	mi/h
Free-flow speed, FFS	58.2	mi/h
Adjustment for no-passing zones, fnp	2.2	mi/h
Average travel speed, ATS	52.6	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.971	
Two-way flow rate, (note-1) vp	371	pc/h
Highest directional split proportion (note-2)	223	
Base percent time-spent-following, BPTSF	27.8	%
Adj. for directional distribution and no-passing zones, fd/np	11.8	
Percent time-spent-following, PTSF	39.6	%

Level of Service and Other Performance Measures

Level of service, LOS	B	
Volume to capacity ratio, v/c	0.14	
Peak 15-min vehicle-miles of travel, VMT15	2026	veh-mi
Peak-hour vehicle-miles of travel, VMT60	7133	veh-mi
Peak 15-min total travel time, TT15	38.5	veh-h

Notes:

1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.

HCS2000: Two-Lane Highways Release 4.1c

Phone:
 E-Mail:

Fax:

Two-Way Two-Lane Highway Segment Analysis

Analyst Danielle Bolan
 Agency/Co. MDT
 Date Performed 10/14/2006
 Analysis Time Period design hour
 Highway US 2
 From/To Culbertson to ND State Line
 Jurisdiction MDT
 Analysis Year 2036 - Median
 Description TRED Corridor

Input Data

Highway class	Class 1			
Shoulder width	2.5	ft	Peak-hour factor, PHF	0.88

Lane width	12.0	ft	% Trucks and buses	30	%
Segment length	22.5	mi	% Recreational vehicles	4	%
Terrain type	Level		% No-passing zones	31	%
Grade: Length		mi	Access points/mi	5	/mi
Up/down		%			

Two-way hourly volume, V	374	veh/h
Directional split	60 / 40	%

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.826	
Two-way flow rate, (note-1) vp	514	pc/h
Highest directional split proportion (note-2)	308	pc/h

Free-Flow Speed from Field Measurement:

Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	62.0	mi/h
Adj. for lane and shoulder width, fLS	2.6	mi/h
Adj. for access points, fA	1.2*	mi/h

Free-flow speed, FFS	58.2	mi/h
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Adjustment for no-passing zones, fnp	2.1	mi/h
Average travel speed, ATS	52.1	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.971	
Two-way flow rate, (note-1) vp	438	pc/h
Highest directional split proportion (note-2)	263	
Base percent time-spent-following, BPTSF	32.0	%
Adj. for directional distribution and no-passing zones, fd/np	14.1	
Percent time-spent-following, PTSF	46.0	%

Level of Service and Other Performance Measures

Level of service, LOS	B	
Volume to capacity ratio, v/c	0.16	
Peak 15-min vehicle-miles of travel, VMT15	2391	veh-mi
Peak-hour vehicle-miles of travel, VMT60	8415	veh-mi
Peak 15-min total travel time, TT15	45.9	veh-h

Notes:

1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.

HCS2000: Two-Lane Highways Release 4.1c

Phone:

Fax:

E-Mail:

Two-Way Two-Lane Highway Segment Analysis

Analyst	Danielle Bolan
Agency/Co.	MDT
Date Performed	10/14/2006
Analysis Time Period	design hour
Highway	US 2
From/To	Culbertson to ND State Line
Jurisdiction	MDT
Analysis Year	2036 - 10% Confidence
Description	TRED Corridor

Input Data

Highway class	Class 1	
Shoulder width	2.5	ft
Lane width	12.0	ft
Segment length	22.5	mi
Terrain type	Level	
Grade: Length		mi
Up/down		%
Peak-hour factor, PHF	0.88	
% Trucks and buses	30	%
% Recreational vehicles	4	%
% No-passing zones	31	%
Access points/mi	5	/mi

Two-way hourly volume, V	427	veh/h
Directional split	60 / 40	%

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.826	
Two-way flow rate, (note-1) vp	587	pc/h
Highest directional split proportion (note-2)	352	pc/h

Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	62.0	mi/h
Adj. for lane and shoulder width, fLS	2.6	mi/h
Adj. for access points, fA	1.2*	mi/h
Free-flow speed, FFS	58.2	mi/h
Adjustment for no-passing zones, fnp	2.1	mi/h
Average travel speed, ATS	51.6	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.971	
Two-way flow rate, (note-1) vp	500	pc/h
Highest directional split proportion (note-2)	300	
Base percent time-spent-following, BPTSF	35.6	%
Adj. for directional distribution and no-passing zones, fd/np	13.9	
Percent time-spent-following, PTSF	49.4	%

Level of Service and Other Performance Measures

Level of service, LOS	B	
Volume to capacity ratio, v/c	0.18	
Peak 15-min vehicle-miles of travel, VMT15	2729	veh-mi
Peak-hour vehicle-miles of travel, VMT60	9608	veh-mi
Peak 15-min total travel time, TT15	52.9	veh-h

Notes:

1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.

HCS2000: Two-Lane Highways Release 4.1c

Phone:	Fax:
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Two-Way Two-Lane Highway Segment Analysis

Analyst	Danielle Bolan
Agency/Co.	MDT
Date Performed	10/14/2006
Analysis Time Period	
Highway	MT 16
From/To	Culbertson to Raymond
Jurisdiction	MDT
Analysis Year	2006
Description	TRED Corridor

Input Data

Highway class	Class 1				
Shoulder width	3.1	ft	Peak-hour factor, PHF	0.88	
Lane width	12.0	ft	% Trucks and buses	8	%
Segment length	62.4	mi	% Recreational vehicles	4	%
Terrain type	Level		% No-passing zones	32	%
Grade: Length		mi	Access points/mi	3	/mi
Up/down		%			
Two-way hourly volume, V	184	veh/h			
Directional split	60 / 40	%			

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.947	
Two-way flow rate, (note-1) vp	221	pc/h
Highest directional split proportion (note-2)	133	pc/h
Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h

Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	62.0	mi/h
Adj. for lane and shoulder width, fLS	2.6	mi/h
Adj. for access points, fA	1.2*	mi/h
Free-flow speed, FFS	58.2	mi/h
Adjustment for no-passing zones, fnp	1.2	mi/h
Average travel speed, ATS	55.3	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.992	
Two-way flow rate, (note-1) vp	211	pc/h
Highest directional split proportion (note-2)	127	
Base percent time-spent-following, BPTSF	16.9	%
Adj. for directional distribution and no-passing zones, fd/np	11.8	
Percent time-spent-following, PTSF	28.7	%

Level of Service and Other Performance Measures

Level of service, LOS	A	
Volume to capacity ratio, v/c	0.07	
Peak 15-min vehicle-miles of travel, VMT15	3262	veh-mi
Peak-hour vehicle-miles of travel, VMT60	11482	veh-mi
Peak 15-min total travel time, TT15	59.0	veh-h

Notes:

1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.

HCS2000: Two-Lane Highways Release 4.1c

Phone:	Fax:
E-Mail:	

Two-Way Two-Lane Highway Segment Analysis

Analyst	Danielle Bolan
Agency/Co.	MDT
Date Performed	10/14/2006
Analysis Time Period	design hour
Highway	MT 16
From/To	Culbertson to Raymond
Jurisdiction	MDT
Analysis Year	2036 - 90% Confidence
Description	TRED Corridor

Input Data

Highway class	Class 1			
Shoulder width	3.1	ft	Peak-hour factor, PHF	0.88
Lane width	12.0	ft	% Trucks and buses	%
Segment length	62.4	mi	% Recreational vehicles	4
Terrain type	Level		% No-passing zones	32
Grade: Length		mi	Access points/mi	3
Up/down		%		/mi

Two-way hourly volume, V	305	veh/h
Directional split	60 / 40	%

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.7	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.790	
Two-way flow rate, (note-1) vp	439	pc/h
Highest directional split proportion (note-2)	263	pc/h
Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	62.0	mi/h
Adj. for lane and shoulder width, fLS	2.6	mi/h
Adj. for access points, fA	1.2*	mi/h
Free-flow speed, FFS	58.2	mi/h
Adjustment for no-passing zones, fnp	2.3	mi/h
Average travel speed, ATS	52.5	mi/h

Percent Time-Spent-Following			
Grade adjustment factor, fG	1.00		
PCE for trucks, ET	1.1		
PCE for RVs, ER	1.0		
Heavy-vehicle adjustment factor, fHV	0.963		
Two-way flow rate, (note-1) vp	360	pc/h	
Highest directional split proportion (note-2)	216		
Base percent time-spent-following, BPTSF	27.1	%	
Adj.for directional distribution and no-passing zones, fd/np	11.8		
Percent time-spent-following, PTSF	38.9	%	

Level of Service and Other Performance Measures			
Level of service, LOS	B		
Volume to capacity ratio, v/c	0.14		
Peak 15-min vehicle-miles of travel, VMT15	5407	veh-mi	
Peak-hour vehicle-miles of travel, VMT60	19032	veh-mi	
Peak 15-min total travel time, TT15	102.9	veh-h	

Notes:

1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
 2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.
- HCS2000: Two-Lane Highways Release 4.1c

Phone:

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E-Mail:

Two-Way Two-Lane Highway Segment Analysis	
Analyst	Danielle Bolan
Agency/Co.	MDT
Date Performed	10/14/2006
Analysis Time Period	design hour
Highway	MT 16
From/To	Culbertson to Raymond
Jurisdiction	MDT
Analysis Year	2036 - Median
Description	TRED Corridor

Input Data					
Highway class	Class 1				
Shoulder width	3.1	ft	Peak-hour factor, PHF	0.88	
Lane width	12.0	ft	% Trucks and buses	32	%
Segment length	62.4	mi	% Recreational vehicles	4	%
Terrain type	Level		% No-passing zones	32	%
Grade: Length		mi	Access points/mi	3	/mi
Up/down		%			
Two-way hourly volume, V	360	veh/h			
Directional split	60	/	40	%	

Average Travel Speed			
Grade adjustment factor, fG	1.00		
PCE for trucks, ET	1.7		
PCE for RVs, ER	1.0		
Heavy-vehicle adjustment factor,	0.817		
Two-way flow rate, (note-1) vp	501	pc/h	
Highest directional split proportion (note-2)	301	pc/h	
Free-Flow Speed from Field Measurement:			
Field measured speed, SFM	-	mi/h	
Observed volume, Vf	-	veh/h	
Estimated Free-Flow Speed:			
Base free-flow speed, BFFS	62.0	mi/h	
Adj. for lane and shoulder width, fLS	2.6	mi/h	
Adj. for access points, fA	1.2*	mi/h	
Free-flow speed, FFS	58.2	mi/h	
Adjustment for no-passing zones, fnp	2.2	mi/h	
Average travel speed, ATS	52.1	mi/h	

Percent Time-Spent-Following			
Grade adjustment factor, fG	1.00		
PCE for trucks, ET	1.1		
PCE for RVs, ER	1.0		
Heavy-vehicle adjustment factor, fHV	0.969		
Two-way flow rate, (note-1) vp	422	pc/h	
Highest directional split proportion (note-2)	253		
Base percent time-spent-following, BPTSF	31.0	%	

Adj.for directional distribution and no-passing zones, fd/np 14.3
 Percent time-spent-following, PTSF 45.3 %

Level of Service and Other Performance Measures

Level of service, LOS	B	
Volume to capacity ratio, v/c	0.16	
Peak 15-min vehicle-miles of travel, VMT15	6382	veh-mi
Peak-hour vehicle-miles of travel, VMT60	22464	veh-mi
Peak 15-min total travel time, TT15	122.4	veh-h

Notes:

1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
 2. If highest directional split vp >= 1700 pc/h, terminate analysis-the LOS is F.
- HCS2000: Two-Lane Highways Release 4.1c

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Two-Way Two-Lane Highway Segment Analysis

Analyst	Danielle Bolan
Agency/Co.	MDT
Date Performed	10/14/2006
Analysis Time Period	design hour
Highway	MT 16
From/To	Culbertson to Raymond
Jurisdiction	MDT
Analysis Year	2036 - 10% Confidence
Description	TRED Corridor

Input Data

Highway class	Class 1			
Shoulder width	3.1	ft	Peak-hour factor, PHF	0.88
Lane width	12.0	ft	% Trucks and buses	38 %
Segment length	62.4	mi	% Recreational vehicles	4 %
Terrain type	Level		% No-passing zones	32 %
Grade: Length		mi	Access points/mi	3 /mi
Up/down		%		

Two-way hourly volume, V	427	veh/h
Directional split	60 / 40	%

Average Travel Speed

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.2	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor,	0.929	
Two-way flow rate, (note-1) vp	522	pc/h
Highest directional split proportion (note-2)	313	pc/h
Free-Flow Speed from Field Measurement:		
Field measured speed, SFM	-	mi/h
Observed volume, Vf	-	veh/h
Estimated Free-Flow Speed:		
Base free-flow speed, BFFS	62.0	mi/h
Adj. for lane and shoulder width, fLS	2.6	mi/h
Adj. for access points, fA	1.2*	mi/h
Free-flow speed, FFS	58.2	mi/h
Adjustment for no-passing zones, fnp	2.2	mi/h
Average travel speed, ATS	52.0	mi/h

Percent Time-Spent-Following

Grade adjustment factor, fG	1.00	
PCE for trucks, ET	1.1	
PCE for RVs, ER	1.0	
Heavy-vehicle adjustment factor, fHV	0.963	
Two-way flow rate, (note-1) vp	504	pc/h
Highest directional split proportion (note-2)	302	
Base percent time-spent-following, BPTSF	35.8	%
Adj.for directional distribution and no-passing zones, fd/np	14.0	
Percent time-spent-following, PTSF	49.8	%

Level of Service and Other Performance Measures

Level of service, LOS	B	
Volume to capacity ratio, v/c	0.16	
Peak 15-min vehicle-miles of travel, VMT15	7570	veh-mi
Peak-hour vehicle-miles of travel, VMT60	26645	veh-mi
Peak 15-min total travel time, TT15	145.6	veh-h

Notes:

1. If $vp \geq 3200$ pc/h, terminate analysis-the LOS is F.
2. If highest directional split $vp \geq 1700$ pc/h, terminate analysis-the LOS is F.